Party Example

```
public class Character {
    private int battlesWon = 0;
    private int expPoints = 0;
    public Character() {}
    public void winBattle(int xp) {
        this.battlesWon++;
        this.expPoints += xp;
public class Party {
    private ArrayList<Character> members;
    private int battlesWon = 0;
    public Party() {
       this.members = new ArrayList<>();
    public void addCharacter(Character member) {
        this.members.add(member);
    public void winBattle(int xp) {
        this.battlesWon++;
        for (int x=0; x < this.members.size(); x++) {</pre>
            this.members.get(x).winBattle(xp);
    public static void main(String[] args) {
        Character hero = new Character();
        hero = new Character();
        Character fighter = new Character();
        hero.winBattle(10);
        Party party = new Party();
        party.addCharacter(hero);
        party.addCharacter(fighter);
        party.winBattle(20);
```

Party

- Let's look at another example using objects
- We'll highlight 2 new concepts with this code:
 - Composition
 - Garbage Collection

```
public class Character {
    private int battlesWon = 0;
    private int expPoints = 0;
    public Character() {}
    public void winBattle(int xp) {
        this.battlesWon++;
        this.expPoints += xp;
public class Party {
   private ArrayList<Character> members;
    private int battlesWon = 0;
    public Party() {
       this.members = new ArrayList<>();
    public void addCharacter(Character member) {
        this.members.add(member);
    public void winBattle(int xp) {
        this.battlesWon++;
        for (int x=0; x < this.members.size(); x++) {</pre>
            this.members.get(x).winBattle(xp);
    public static void main(String[] args) {
        Character hero = new Character();
        hero = new Character();
        Character fighter = new Character();
        hero.winBattle(10);
        Party party = new Party();
        party.addCharacter(hero);
        party.addCharacter(fighter);
        party.winBattle(20);
```

Composition

- Instance variables of objects can store references to other objects
- The Party class is composed of an ArrayList of Characters

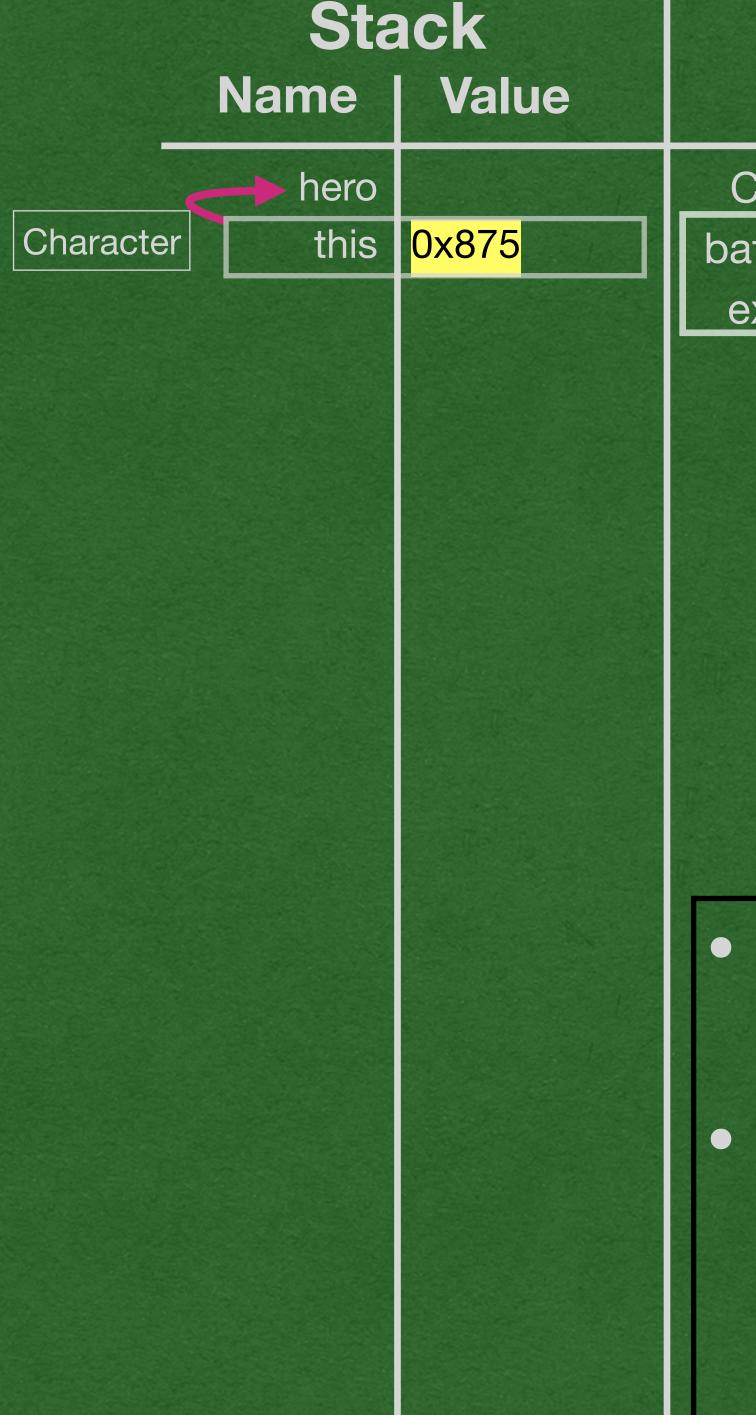
```
public class Character {
    private int battlesWon = 0;
    private int expPoints = 0;
    public Character() {}
    public void winBattle(int xp) {
        this.battlesWon++;
        this.expPoints += xp;
public class Party {
    private ArrayList<Character> members;
    private int battlesWon = 0;
    public Party() {
       this.members = new ArrayList<>();
    public void addCharacter(Character member) {
        this.members.add(member);
    public void winBattle(int xp) {
        this.battlesWon++;
        for (int x=0; x < this.members.size(); x++) {</pre>
            this.members.get(x).winBattle(xp);
    public static void main(String[] args) {
        Character hero = new Character();
       hero = new Character();
        Character fighter = new Character();
        hero.winBattle(10);
        Party party = new Party();
        party.addCharacter(hero);
        party.addCharacter(fighter);
        party.winBattle(20);
```

Garbage Collection

- hero is assigned a reference to an instance/object of type Character
- hero is then reassigned to a new reference
- We no longer have a reference to the first Character object in memory
 - Since we cannot access this object, it will be removed from memory

Memory Diagram

```
public class Character {
    private int battlesWon = 0;
    private int expPoints = 0;
    public Character() {}
    public void winBattle(int xp) {
        this.battlesWon++;
        this.expPoints += xp;
public class Party {
  private ArrayList<Character> members;
  private int battlesWon = 0;
  public Party() {
   this.members = new ArrayList<>();
  public void addCharacter(Character member) {
    this.members.add(member);
  public void winBattle(int xp) {
    this battlesWon++;
    for (int x=0; x < this.members.size(); x++) {</pre>
      this.members.get(x).winBattle(xp);
  public static void main(String[] args) {
    Character hero = new Character();
    hero = new Character();
    Character fighter = new Character();
    hero.winBattle(10);
    Party party = new Party();
    party.addCharacter(hero);
    party.addCharacter(fighter);
    party.winBattle(20);
```





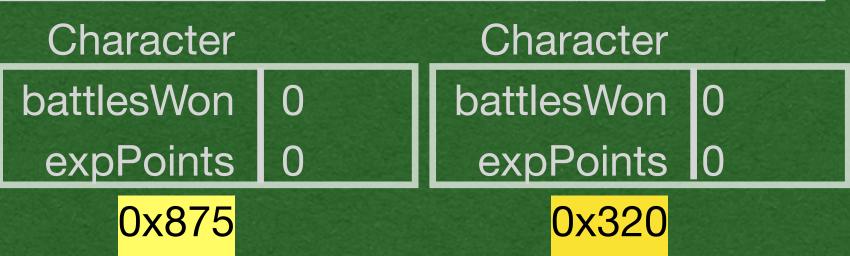
- Start by creating a new
 Character object
- The constructor is empty, but we still create the instance variables

```
public class Character {
    private int battlesWon = 0;
    private int expPoints = 0;

    public Character() {}
    public void winBattle(int xp) {
        this.battlesWon++;
        this.expPoints += xp;
    }
}
```

```
public class Party {
  private ArrayList<Character> members;
  private int battlesWon = 0;
  public Party() {
   this.members = new ArrayList<>();
  public void addCharacter(Character member) {
    this.members.add(member);
  public void winBattle(int xp) {
    this battlesWon++;
    for (int x=0; x < this.members.size(); x++) {</pre>
      this.members.get(x).winBattle(xp);
  public static void main(String[] args) {
    Character hero = new Character();
   hero = new Character();
    Character fighter = new Character();
    hero.winBattle(10);
    Party party = new Party();
    party.addCharacter(hero);
    party.addCharacter(fighter);
    party.winBattle(20);
```





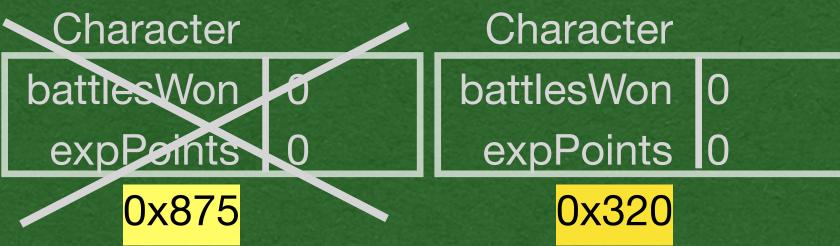
- We immediately replace the reference stored in hero with a reference to a new object
- *You wouldn't actually do this. This is only for the example

```
public class Character {
    private int battlesWon = 0;
    private int expPoints = 0;

    public Character() {}
    public void winBattle(int xp) {
        this.battlesWon++;
        this.expPoints += xp;
    }
}
```

```
public class Party {
  private ArrayList<Character> members;
  private int battlesWon = 0;
  public Party() {
   this.members = new ArrayList<>();
  public void addCharacter(Character member) {
    this.members.add(member);
  public void winBattle(int xp) {
    this battlesWon++;
    for (int x=0; x < this.members.size(); x++) {</pre>
      this.members.get(x).winBattle(xp);
  public static void main(String[] args) {
    Character hero = new Character();
   hero = new Character();
    Character fighter = new Character();
    hero.winBattle(10);
    Party party = new Party();
    party.addCharacter(hero);
    party.addCharacter(fighter);
    party.winBattle(20);
```





in/out

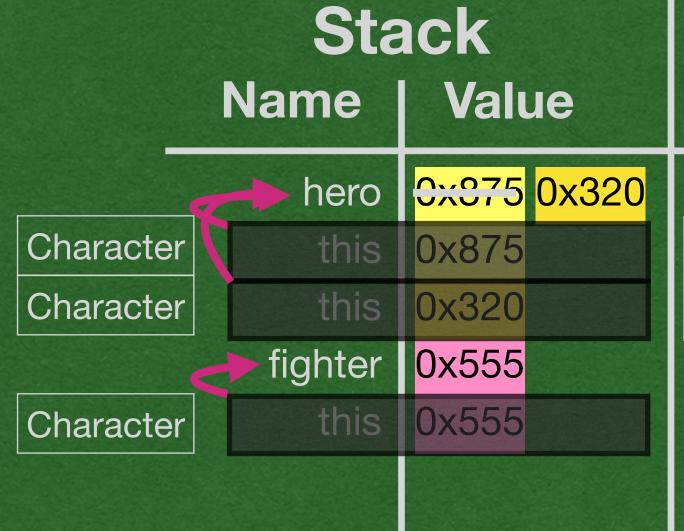
Garbage Collection

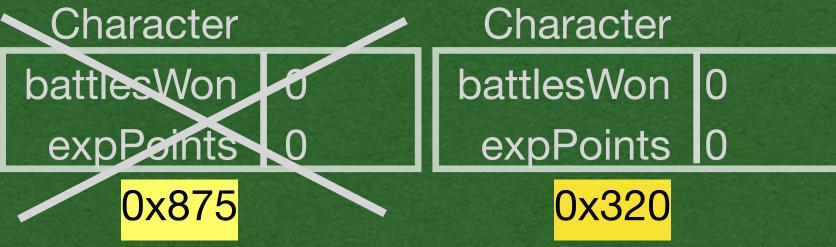
- When we no longer have access to a reference to an object on the heap, it is deleted from memory
- Java does this in the background as we reassign variables

```
public class Character {
    private int battlesWon = 0;
    private int expPoints = 0;

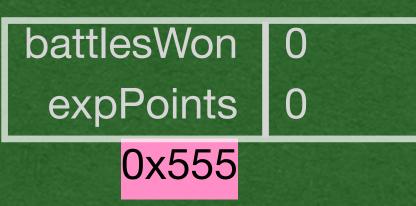
    public Character() {}
    public void winBattle(int xp) {
        this.battlesWon++;
        this.expPoints += xp;
    }
}
```

```
public class Party {
 private ArrayList<Character> members;
  private int battlesWon = 0;
 public Party() {
   this.members = new ArrayList<>();
  public void addCharacter(Character member) {
    this.members.add(member);
  public void winBattle(int xp) {
   this battlesWon++;
    for (int x=0; x < this.members.size(); x++) {</pre>
      this.members.get(x).winBattle(xp);
 public static void main(String[] args) {
    Character hero = new Character();
   hero = new Character();
   Character fighter = new Character();
   hero.winBattle(10);
    Party party = new Party();
    party.addCharacter(hero);
    party.addCharacter(fighter);
   party.winBattle(20);
```





Character

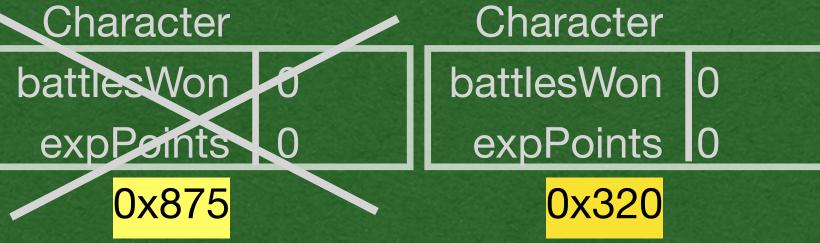


in/out

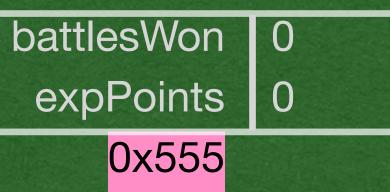
Create another instance of the Character class (Object of type character)

```
public class Character {
    private int battlesWon = 0;
    private int expPoints = 0;
    public Character() {}
public void winBattle(int xp) {
        this.battlesWon++;
        this.expPoints += xp;
public class Party {
  private ArrayList<Character> members;
  private int battlesWon = 0;
  public Party() {
   this.members = new ArrayList<>();
  public void addCharacter(Character member) {
    this.members.add(member);
  public void winBattle(int xp) {
    this battlesWon++;
    for (int x=0; x < this.members.size(); x++) {</pre>
      this.members.get(x).winBattle(xp);
  public static void main(String[] args) {
    Character hero = new Character();
    hero = new Character();
    Character fighter = new Character();
   hero.winBattle(10);
    Party party = new Party();
    party.addCharacter(hero);
    party.addCharacter(fighter);
    party.winBattle(20);
```





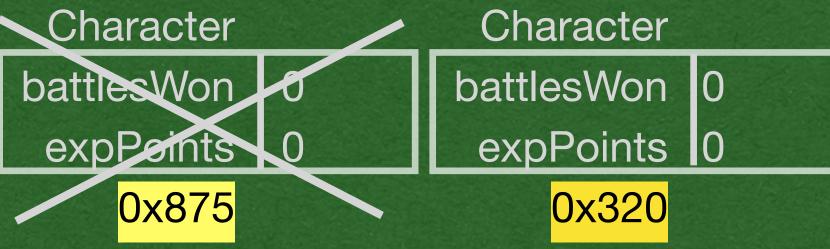
Character



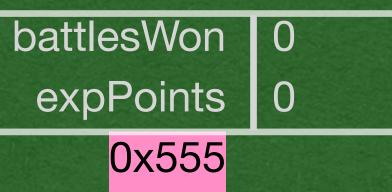
- When we call a method:
 - this is added to the stack frame
- this stores reference to the calling object

```
public class Character {
    private int battlesWon = 0;
    private int expPoints = 0;
    public Character() {}
public void winBattle(int xp) {
        this.battlesWon++;
        this.expPoints += xp;
public class Party {
  private ArrayList<Character> members;
  private int battlesWon = 0;
  public Party() {
   this.members = new ArrayList<>();
  public void addCharacter(Character member) {
    this.members.add(member);
  public void winBattle(int xp) {
    this battlesWon++;
    for (int x=0; x < this.members.size(); x++) {</pre>
      this.members.get(x).winBattle(xp);
  public static void main(String[] args) {
    Character hero = new Character();
    hero = new Character();
    Character fighter = new Character();
   hero.winBattle(10);
    Party party = new Party();
    party.addCharacter(hero);
    party.addCharacter(fighter);
    party.winBattle(20);
```





Character

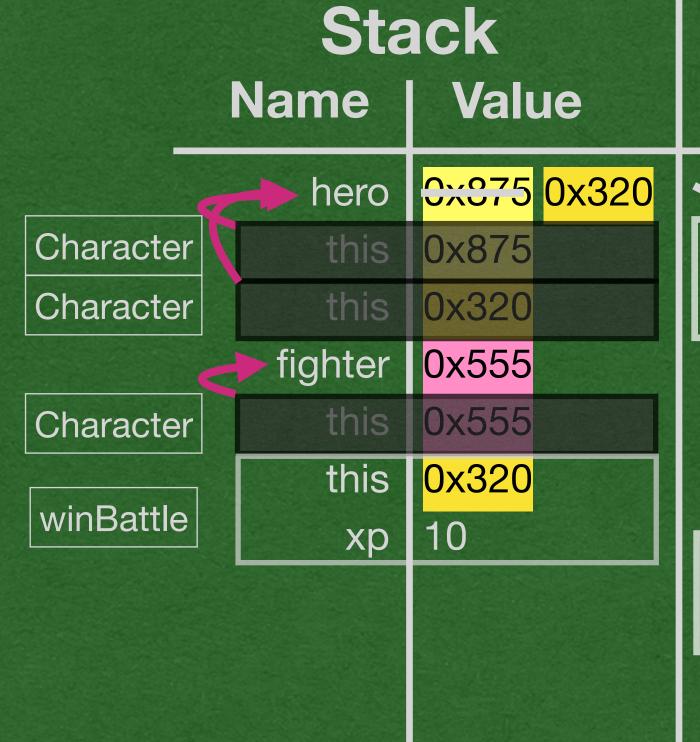


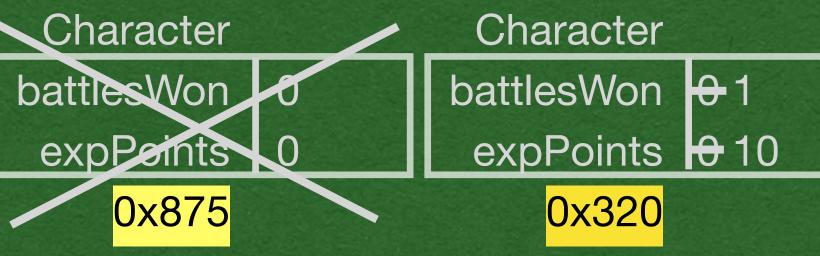
- winBattle was called by hero
- hero stores the reference 0x320
- this in the stack frame is 0x320

```
public class Character {
    private int battlesWon = 0;
    private int expPoints = 0;

public Character() {}
    public void winBattle(int xp) {
        this.battlesWon++;
        this.expPoints += xp;
}
```

```
public class Party {
  private ArrayList<Character> members;
  private int battlesWon = 0;
  public Party() {
   this.members = new ArrayList<>();
  public void addCharacter(Character member) {
    this.members.add(member);
  public void winBattle(int xp) {
    this battlesWon++;
    for (int x=0; x < this.members.size(); x++) {</pre>
      this.members.get(x).winBattle(xp);
  public static void main(String[] args) {
    Character hero = new Character();
    hero = new Character();
    Character fighter = new Character();
hero.winBattle(10);
    Party party = new Party();
    party.addCharacter(hero);
    party.addCharacter(fighter);
    party.winBattle(20);
```





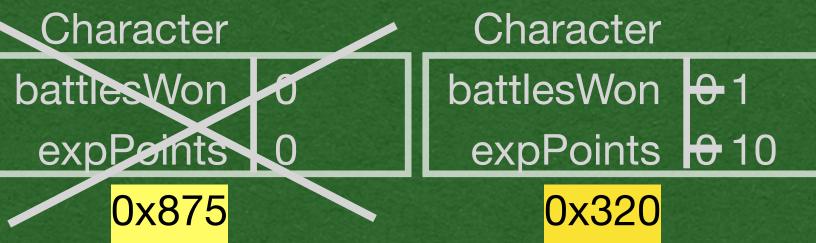
Character

in/out

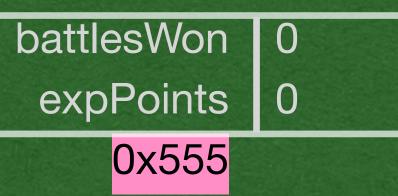
 Follow the reference stored in this to update the instance variables

```
public class Character {
    private int battlesWon = 0;
    private int expPoints = 0;
    public Character() {}
    public void winBattle(int xp) {
        this.battlesWon++;
        this.expPoints += xp;
public class Party {
  private ArrayList<Character> members;
  private int battlesWon = 0;
  public Party() {
   this.members = new ArrayList<>();
  public void addCharacter(Character member) {
    this.members.add(member);
  public void winBattle(int xp) {
    this battlesWon++;
    for (int x=0; x < this.members.size(); x++) {</pre>
      this.members.get(x).winBattle(xp);
  public static void main(String[] args) {
    Character hero = new Character();
    hero = new Character();
    Character fighter = new Character();
hero.winBattle(10);
 Party party = new Party();
    party.addCharacter(hero);
    party.addCharacter(fighter);
    party.winBattle(20);
```



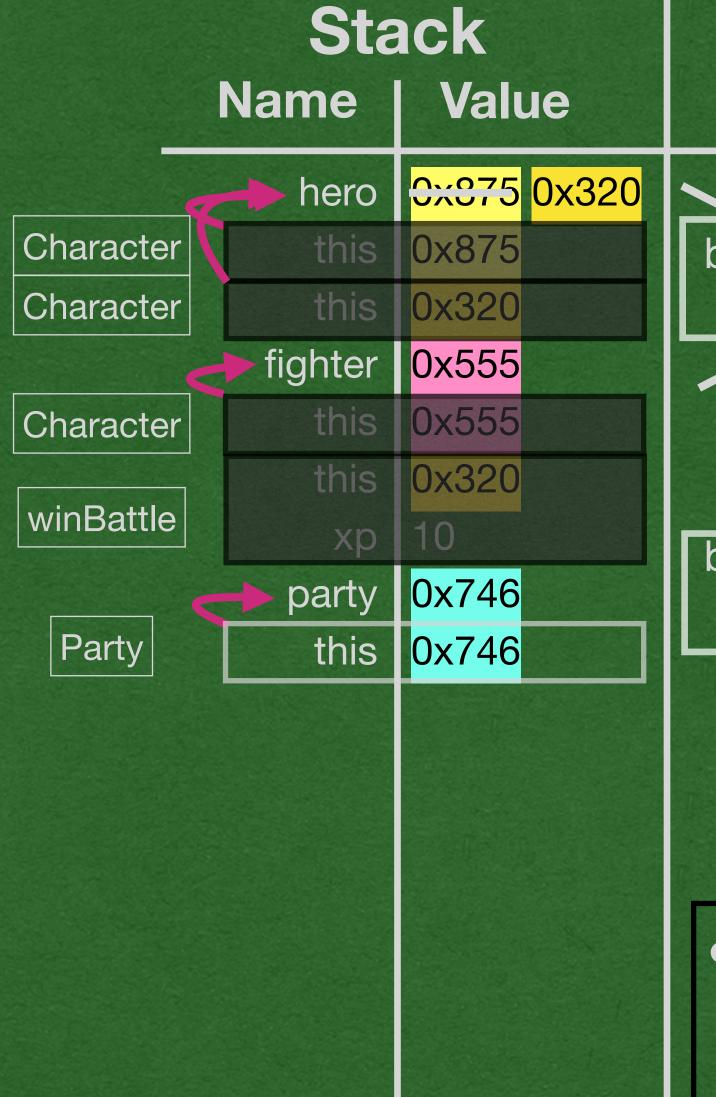


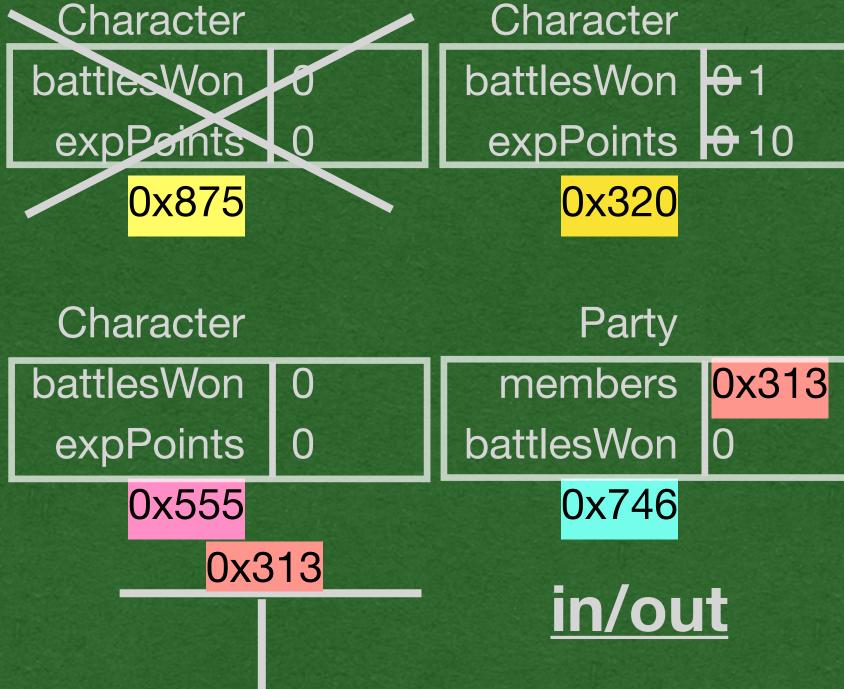
Character



- This method's got sideeffects!
- winBattle returns void
- winBattle was called to change the state of an object on the heap

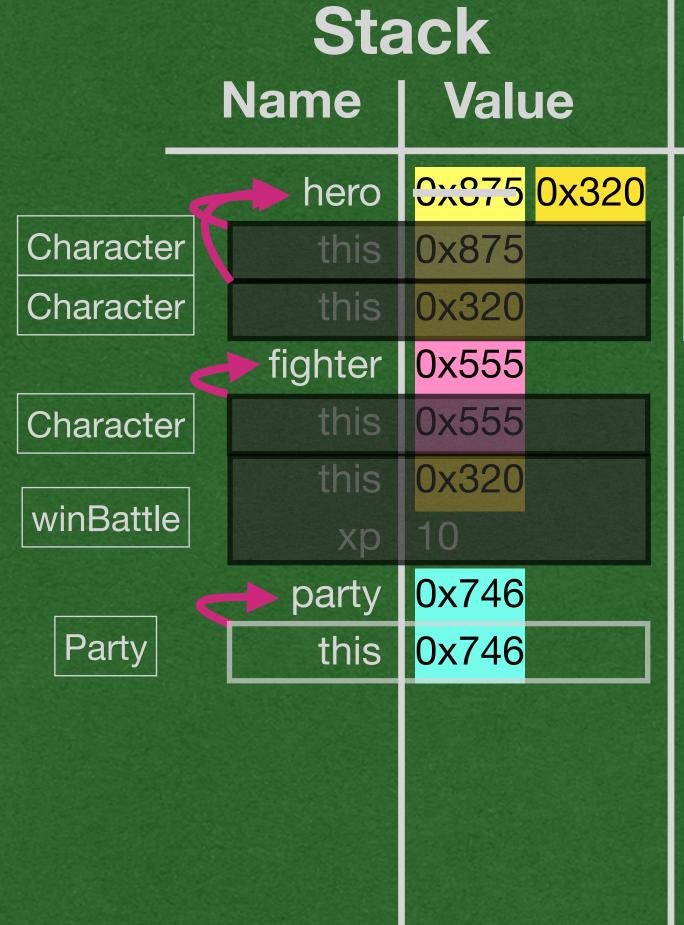
```
public class Character {
     private int battlesWon = 0;
     private int expPoints = 0;
     public Character() {}
     public void winBattle(int xp) {
         this.battlesWon++;
         this.expPoints += xp;
public class Party {
  private ArrayList<Character> members;
  private int battlesWon = 0;
   public Party() {
this members = new ArrayList<>();
  public void addCharacter(Character member) {
     this.members.add(member);
   public void winBattle(int xp) {
    this battlesWon++;
     for (int x=0; x < this.members.size(); x++) {</pre>
       this.members.get(x).winBattle(xp);
   public static void main(String[] args) {
     Character hero = new Character();
    hero = new Character();
    Character fighter = new Character();
    hero.winBattle(10);
Party party = new Party();
    party.addCharacter(hero);
    party.addCharacter(fighter);
    party.winBattle(20);
```

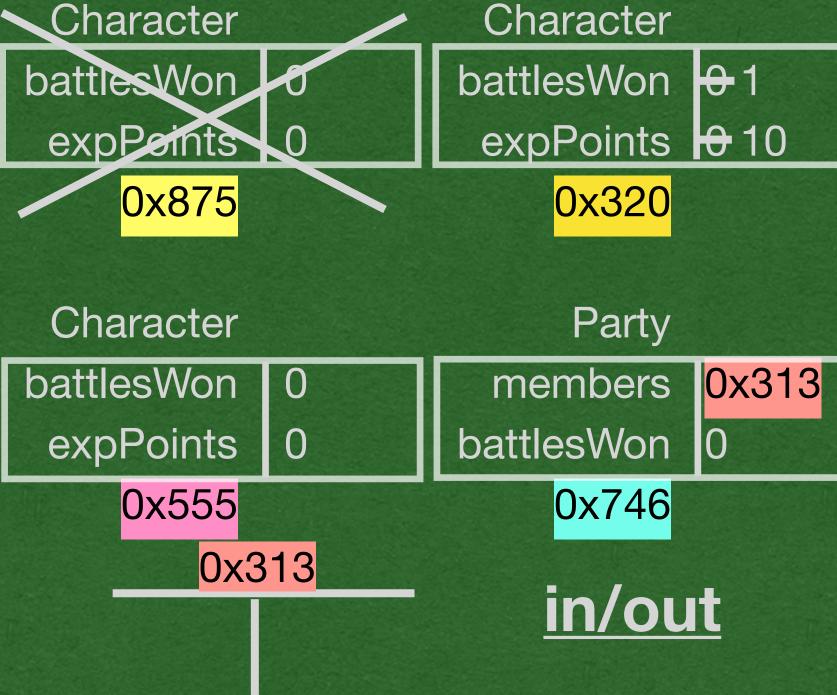




- When we create a new Party, we also create a new ArrayList via composition
- Both objects are created on the heap

```
public class Character {
     private int battlesWon = 0;
     private int expPoints = 0;
     public Character() {}
     public void winBattle(int xp) {
         this.battlesWon++;
         this.expPoints += xp;
public class Party {
  private ArrayList<Character> members;
  private int battlesWon = 0;
   public Party() {
this members = new ArrayList<>();
  public void addCharacter(Character member) {
     this.members.add(member);
   public void winBattle(int xp) {
     this.battlesWon++;
     for (int x=0; x < this.members.size(); x++) {</pre>
       this.members.get(x).winBattle(xp);
   public static void main(String[] args) {
     Character hero = new Character();
    hero = new Character();
    Character fighter = new Character();
    hero.winBattle(10);
Party party = new Party();
    party.addCharacter(hero);
     party.addCharacter(fighter);
    party.winBattle(20);
```





- The is a stack frame created for the ArrayList constructor
- When the code is part of Java, and not our code, we don't add it to the memory diagram

```
Stack
public class Character {
                                                                                                    Heap
   private int battlesWon = 0;
                                                                       Value
                                                            Name |
   private int expPoints = 0;
   public Character() {}
                                                                hero 0x375 0x320
                                                                                     Character
                                                                                                           Character
   public void winBattle(int xp) {
                                                  Character
                                                                 this | 0x875
                                                                                    battles Won 0
                                                                                                          battlesWon 0-1
       this.battlesWon++;
       this.expPoints += xp;
                                                  Character
                                                                 this | 0x320
                                                                                                           expPoints 0 10
                                                                                     expPeints 0
                                                              fighter 0x555
                                                                                         0x875
                                                                                                               0x320
                                                                 this 0x555
                                                  Character
public class Party {
 private ArrayList<Character> members;
                                                                 this 0x320
                                                                                      Character
                                                                                                                Party
 private int battlesWon = 0;
                                                  winBattle
                                                                                    battlesWon 0
                                                                                                            members 0x313
 public Party() {
                                                               party 0x746
  this.members = new ArrayList<>();
                                                                                                          battlesWon 0
                                                                                      expPoints
                                                    Party
                                                                 this | 0x746
                                                                                         0x555
                                                                                                               0x746
 public void addCharacter(Character member) {
                                                                 this 0x746
   this.members.add(member);
                                                addCharacter
                                                                                             0x313
                                                             member 0x320
                                                                                                              in/out
                                                                                                 0x320
 public void winBattle(int xp) {
   this battlesWon++;
   for (int x=0; x < this.members.size(); x++) {</pre>
     this.members.get(x).winBattle(xp);

    addCharacter takes a reference

                                                                                       to a Character as a parameter
 public static void main(String[] args) {
   Character hero = new Character();
                                                                                      dot means "follow the
   hero = new Character();
   Character fighter = new Character();
                                                                                       reference"
   hero.winBattle(10);
   Party party = new Party();
party.addCharacter(hero);

    We follow 2 references in one

   party.addCharacter(fighter);
                                                                                       line to get to the ArrayList in
   party.winBattle(20);
                                                                                       memory
```

```
Stack
public class Character {
                                                                                                    Heap
    private int battlesWon = 0;
                                                                       Value
                                                            Name I
   private int expPoints = 0;
   public Character() {}
                                                                hero 0x375 0x320
                                                                                     Character
                                                                                                            Character
    public void winBattle(int xp) {
                                                  Character
                                                                 this | 0x875
                                                                                     battlesWon 0
                                                                                                          battlesWon 0-1
       this.battlesWon++;
       this.expPoints += xp;
                                                                 this | 0x320
                                                  Character
                                                                                                            expPoints 0 10
                                                                                      expPeints 0
                                                               fighter 0x555
                                                                                          0x875
                                                                                                               0x320
                                                                 this 0x555
                                                  Character
public class Party {
 private ArrayList<Character> members;
                                                                 this 0x320
                                                                                      Character
                                                                                                                Party
  private int battlesWon = 0;
                                                  winBattle
                                                                                     battlesWon 0
                                                                                                            members 0x313
 public Party() {
                                                               party 0x746
  this.members = new ArrayList<>();
                                                                                                          battlesWon <del>0</del> 1
                                                                                      expPoints
                                                    Party
                                                                 this | 0x746
                                                                                         0x555
                                                                                                               0x746
  public void addCharacter(Character member) {
                                                                 this | 0x746
   this.members.add(member);
                                                addCharacter
                                                                                             0x313
                                                             member
                                                                      0x320
                                                                                                               in/out
                                                                                                 0x320
 public void winBattle(int xp) {
                                                                 this | 0x746
   this battlesWon++;
                                                addCharacter
                                                                                                 0x555
   for (int x=0; x < this.members.size(); x++) {</pre>
                                                                      0x555
                                                             member
     this.members.get(x).winBattle(xp);
                                                                 this 0x746

    Check out this line!

                                                  winBattle
                                                                  xp 20
  public static void main(String[] args) {
                                                                                        dot means follow the
   Character hero = new Character();
   hero = new Character();
                                                                                        reference
   Character fighter = new Character();
   hero.winBattle(10);
   Party party = new Party();
                                                                                       We'll jump around in
   party.addCharacter(hero);
   party.addCharacter(fighter);
                                                                                        memory 3 times to reach
    party.winBattle(20);
                                                                                        the Player at 0x320
```

```
Stack
public class Character {
    private int battlesWon = 0;
                                                                           Value
                                                               Name |
    private int expPoints = 0;
    public Character() {}
                                                                    hero 0x375 0x320
    public void winBattle(int xp) {
                                                     Character
                                                                     this | 0x875
        this battlesWon++;
        this.expPoints += xp;
                                                     Character
                                                                     this | 0x320
                                                                  fighter 0x555
                                                                     this 0x555
                                                     Character
public class Party {
  private ArrayList<Character> members;
                                                                    this 0x320
  private int battlesWon = 0;
                                                     winBattle
  public Party() {
                                                                   party 0x746
   this.members = new ArrayList<>();
                                                       Party
                                                                     this | 0x746
  public void addCharacter(Character member) {
                                                                    this | 0x746
    this.members.add(member);
                                                   addCharacter
                                                                member
                                                                         0x320
  public void winBattle(int xp) {
                                                                    this | 0x746
    this battlesWon++;
                                                   addCharacter
    for (int x=0; x < this.members.size(); x++) {</pre>
                                                                         0x555
                                                                 member
     this.members.get(x).winBattle(xp);
                                                                    this 0x746
                                                     winBattle
                                                                     xp 20
  public static void main(String[] args) {
    Character hero = new Character();
    hero = new Character();
                                                                    this 0x320
                                                     winBattle
    Character fighter = new Character();
                                                                     xp 20
    hero.winBattle(10);
    Party party = new Party();
    party.addCharacter(hero);
    party.addCharacter(fighter);
    party.winBattle(20);
```



- Since we were at 0x320 in memory when this method is called
 - 0x320 is the calling object
 - this stores 0x320

```
public class Character {
    private int battlesWon = 0;
    private int expPoints = 0;
    public Character() {}
    public void winBattle(int xp) {
                                                      Character
        this battlesWon++;
        this.expPoints += xp;
                                                      Character
                                                      Character
public class Party {
  private ArrayList<Character> members;
  private int battlesWon = 0;
                                                      winBattle
  public Party() {
   this.members = new ArrayList<>();
                                                        Party
  public void addCharacter(Character member) {
    this.members.add(member);
                                                    addCharacter
  public void winBattle(int xp) {
    this battlesWon++;
                                                    addCharacter
    for (int x=0; x < this.members.size(); x++) {</pre>
     this.members.get(x).winBattle(xp);
```

public static void main(String[] args) {

Character fighter = new Character();

Character hero = new Character();

hero = new Character();

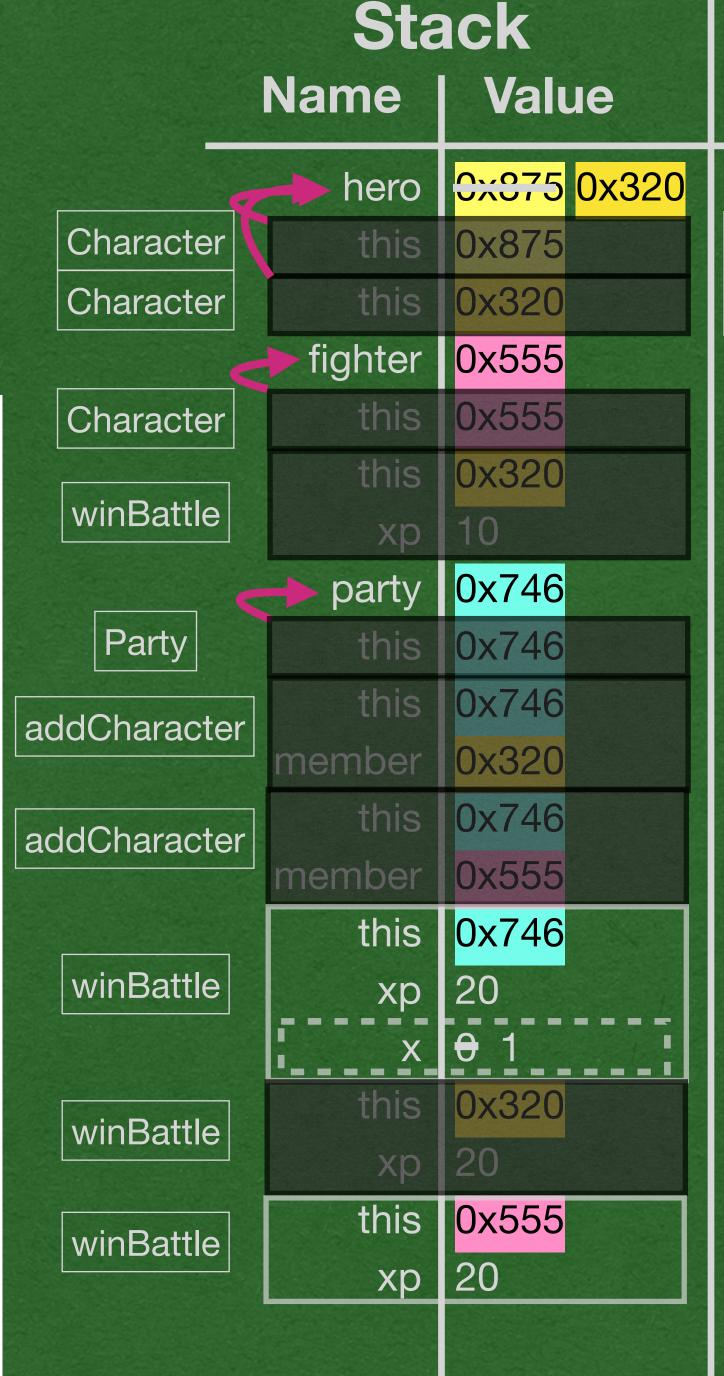
Party party = new Party();

party.addCharacter(fighter);

party.addCharacter(hero);

hero.winBattle(10);

party.winBattle(20);







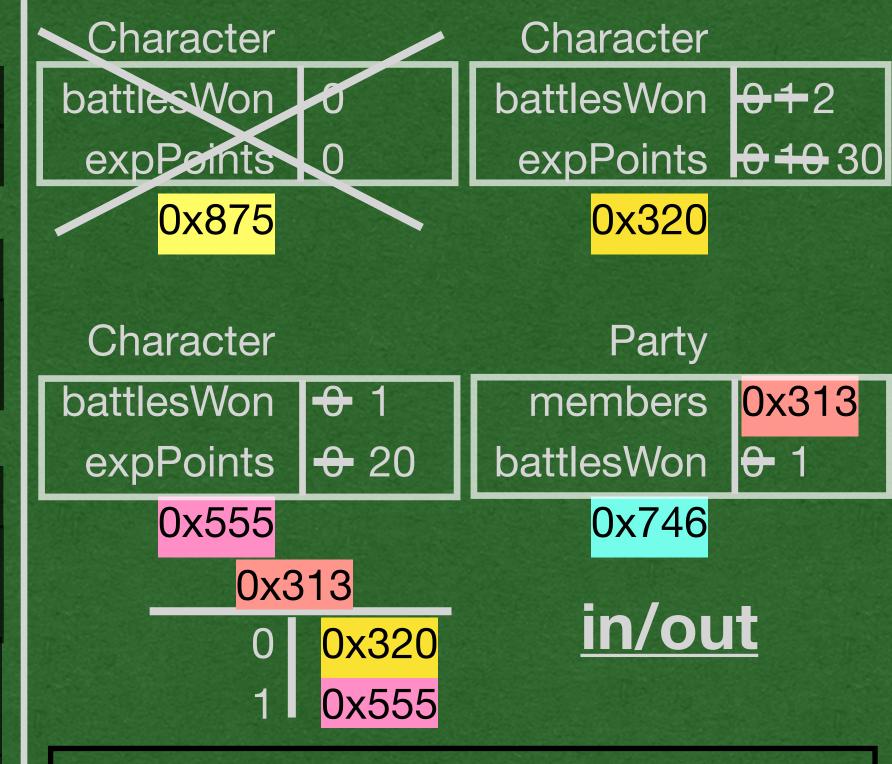
Repeat the process
 with 0x555

```
Stack
public class Character {
                                                                                                    Heap
    private int battlesWon = 0;
                                                                       Value
                                                            Name |
   private int expPoints = 0;
    public Character() {}
                                                                hero 0x375 0x320
                                                                                     Character
                                                                                                           Character
    public void winBattle(int xp) {
                                                  Character
                                                                 this | 0x875
                                                                                    battles Won 0
                                                                                                          battlesWon <del>0 1</del>2
       this.battlesWon++;
       this.expPoints += xp;
                                                  Character
                                                                 this | 0x320
                                                                                                           expPoints 0 10 30
                                                                                     expPeints 0
                                                              fighter 0x555
                                                                                         0x875
                                                                                                               0x320
                                                                 this 0x555
                                                  Character
public class Party {
 private ArrayList<Character> members;
                                                                 this 0x320
                                                                                      Character
                                                                                                                Party
 private int battlesWon = 0;
                                                  winBattle
                                                                                    battlesWon
                                                                                                 +
                                                                                                            members 0x313
 public Party() {
                                                               party 0x746
  this.members = new ArrayList<>();
                                                                                      expPoints + 20
                                                                                                          battlesWon 0 1
                                                    Party
                                                                 this | 0x746
                                                                                         0x555
                                                                                                               0x746
 public void addCharacter(Character member) {
                                                                 this | 0x746
   this.members.add(member);
                                                addCharacter
                                                                                             0x313
                                                             member
                                                                      0x320
                                                                                                              in/out
                                                                                                 0x320
 public void winBattle(int xp) {
                                                                 this | 0x746
   this battlesWon++;
                                                addCharacter
                                                                                                 0x555
   for (int x=0; x < this.members.size(); x++) {</pre>
                                                                     0x555
                                                             member
     this.members.get(x).winBattle(xp);
                                                                 this 0x746

    The loop ends

                                                  winBattle
                                                                  xp 20
 public static void main(String[] args) {
                                                                                         when x reaches 2
   Character hero = new Character();
   hero = new Character();
                                                                 this | 0x320
                                                  winBattle
   Character fighter = new Character();
   hero.winBattle(10);
                                                                                         x is removed from
   Party party = new Party();
                                                                 this 0x555
                                                  winBattle
   party.addCharacter(hero);
                                                                  xp 20
   party.addCharacter(fighter);
                                                                                         memory
   party.winBattle(20);
```

```
Stack
public class Character {
    private int battlesWon = 0;
                                                                           Value
                                                                Name |
    private int expPoints = 0;
    public Character() {}
                                                                    hero 0x375 0x320
    public void winBattle(int xp) {
                                                     Character
                                                                     this | 0x875
        this.battlesWon++;
        this.expPoints += xp;
                                                                     this | 0x320
                                                     Character
                                                                  fighter 0x555
                                                                     this 0x555
                                                     Character
public class Party {
  private ArrayList<Character> members;
                                                                     this 0x320
  private int battlesWon = 0;
                                                     winBattle
  public Party() {
                                                                   party 0x746
   this.members = new ArrayList<>();
                                                       Party
                                                                     this | 0x746
  public void addCharacter(Character member) {
                                                                     this | 0x746
    this.members.add(member);
                                                   addCharacter
                                                                 member
                                                                          0x320
  public void winBattle(int xp) {
                                                                     this | 0x746
    this battlesWon++;
                                                   addCharacter
    for (int x=0; x < this.members.size(); x++) {</pre>
                                                                 member
                                                                          0x555
      this.members.get(x).winBattle(xp);
                                                                     this | 0x746
                                                     winBattle
  public static void main(String[] args) {
    Character hero = new Character();
    hero = new Character();
                                                                     this 0x320
                                                     winBattle
    Character fighter = new Character();
    hero.winBattle(10);
    Party party = new Party();
                                                                     this 0x555
                                                     winBattle
    party.addCharacter(hero);
                                                                      xp 20
    party.addCharacter(fighter);
    party.winBattle(20);
```



- The method calls end
- The program ends